

## Le reazioni di ossidoriduzione e loro bilanciamento

Le **reazioni di ossidoriduzioni** o **redox** sono reazioni nelle quali si ha variazione del *numero di ossidazione* ( *n. o.* ) di ioni o atomi.

La specie chimica che si **ossida** cede elettroni ed aumenta il numero di ossidazione.

La specie chimica che si **riduce** acquista quegli elettroni, diminuendo il numero di ossidazione.

Ovviamente la specie chimica che si ossida funge da *riducente* mentre, al contrario, quella che si riduce funge da *ossidante*.

In una reazione ossidoriduttiva il bilancio delle cariche deve essere uguale a zero.

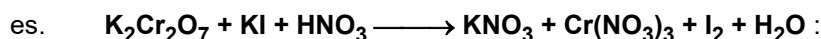
Le reazioni redox possono essere proposte in due modi: in forma molecolare ed in forma ionica.

**Reazioni redox in forma molecolare:** in esse sono descritti tutti gli atomi, per lo più in forma di molecole indissociate, che partecipano alla reazione complessiva, anche quelli che non entrano nella redox, in quanto non subiscono variazioni del *n.o.* .

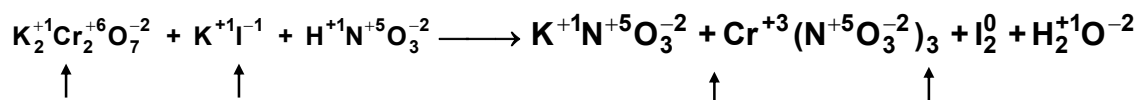
**Reazioni redox in forma ionica:** in esse sono riportati solo gli ioni e le molecole indissociate nelle quali avviene un cambiamento del *n.o.* ; tra i reagenti si trovano anche ioni  $H^+$  , o ioni  $OH^-$  ovvero molecole di  $H_2O$  a seconda che la reazione avvenga in ambiente acido, basico o neutro; anche nei prodotti di reazione si trovano ioni  $H^+$  o ioni  $OH^-$ , ovvero molecole di  $H_2O$  per il bilanciamento complessivo delle cariche. Le molecole di  $H_2O$  possono provenire da combinazione di ioni  $H^+$  con ossigeno ceduto dalla specie ossidante o dalla reazione  $4OH^- \longrightarrow 2H_2O + O_2$  .

Quando possibile è, quindi, preferibile rendere le reazioni molecolari in forma ionica con il seguente metodo:

- 1) - Si attribuisce ad ogni atomo il *n.o.* e si verifica in quali esso subisca una variazione.
- 2) - Si dissociano in ioni le molecole in cui degli atomi abbiano subito modificazioni di *n.o.* . Questa dissociazione avviene per lo più per sali, acidi e basi mentre non si dissociano le molecole biatomiche dei gas, gli ossidi di qualsiasi tipo ed alcune molecole binarie quali  $NH_3$  ,  $PH_3$  .
- 3) - Si osserva in quale ambiente avviene la reazione ( acido, basico o neutro ) .
- 4) - Si scrive la reazione in forma ionica netta, comprendendo, quindi:
  - a) - Ioni e molecole in cui varia il *n.o.*
  - b) - Ioni  $H^+$  o ioni  $OH^-$  , ovvero molecole di  $H_2O$  a seconda dell'ambiente di reazione.
  - c) - Ioni  $H^+$  o ioni  $OH^-$  , ovvero molecole di  $H_2O$  per il bilanciamento delle cariche.



si assegnano i numeri di ossidazione:

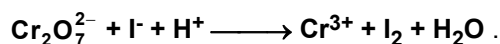


Le specie chimiche che modificano il *n.o.* e che, quindi, entrano nella redox sono quelle indicate.

Nel caso del  $K_2Cr_2O_7$  solo **Cr** modifica il *n.o.* ma è necessario indicare tutto lo ione poliatomico  $Cr_2O_7^{2-}$  piuttosto che lo singolo ione. Tale procedura si dovrà rispettare anche nel caso degli altri residui acidi ( es.  $NO_3^-$  ,  $SO_4^{2-}$  ,  $CO_3$  , etc. ).

L'ambiente è acido per presenza di  $HNO_3$  , per cui si riportano gli ioni  $H^+$ .

La reazione è così resa in forma ionica netta e non bilanciata:



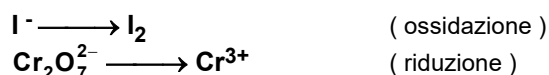
## Bilanciamento delle redox con il metodo delle semireazioni

Bilanciare una reazione significa attribuire ad ogni sostanza presente i coefficienti stechiometrici, in modo che sia possibile la conservazione della massa e la conservazione delle cariche elettriche.

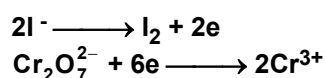
In altre parole il numero di atomi, per ogni specie chimica, presente nei reagenti deve essere eguale al numero di atomi della stessa specie chimica presente nei prodotti di reazione; la carica elettrica complessiva delle sostanze reagenti deve essere uguale alla carica complessiva dei prodotti.

Le procedure per il bilanciamento sono varie; quella che si basa sul metodo delle semireazioni o metodo ionico-elettronico può essere così descritta, utilizzando la reazione in **ambiente acido** già proposta:

- 1) - Si scrivono separatamente le semireazioni di ossidazione e di riduzione:



- 2) - Si bilanciano gli atomi e gli ioni; si indicano gli elettroni in movimento:

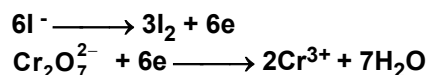


- 3) - Se il numero di elettroni in gioco nelle due semireazioni non è uguale, si calcola il m.c.m. ( minimo comune multiplo ) dei due valori e lo si divide per il numero di elettroni in ogni semireazione. Il coefficiente ottenuto deve essere moltiplicato per il numero degli elettroni, degli atomi e degli ioni di ciascuna semireazione:

m.c.m. tra 6 e 2 = 6 ; si divide questo valore per il numero degli elettroni nelle due semireazioni:



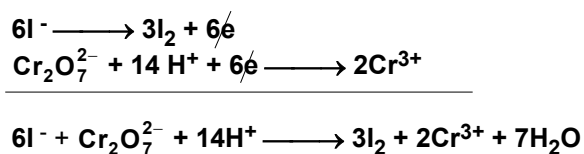
- 4) - Essendo presente dell'ossigeno, è necessario bilanciarlo con delle molecole di H<sub>2</sub>O:



- 5) - Si bilancia l'idrogeno dell'acqua con degli ioni H<sup>+</sup> ( ambiente acido ); si controlla il bilanciamento delle cariche:

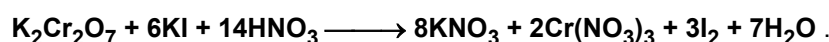


- 6) - Si esegue la somma algebrica delle due semireazioni, effettuando le necessarie semplificazioni:



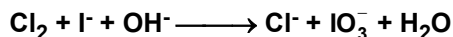
La reazione ionica è così bilanciata.

A questo punto è possibile scrivere la reazione bilanciata anche in forma molecolare:

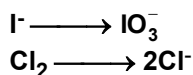


La stessa procedura deve essere utilizzata anche nel caso di reazioni in **ambiente basico**:

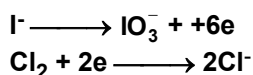
Si consideri la reazione in ambiente basico:



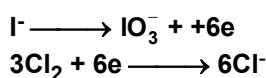
1) - Si scrivono separatamente le semireazioni di ossidazione e di riduzione:



2) - Si bilanciano gli atomi e si indicano gli elettroni in movimento:

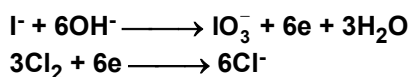


3) - Si calcola il m.c.m. e con tale valore si bilanciano gli elettroni, modificando il numero degli atomi; m.c.m. tra 6 e 2 = 6:



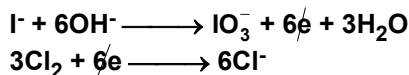
$6 : 6 = 1$ ( non serve moltiplicare ) $6 : 2 = 3$ ( coefficiente moltiplicatore )
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4) - Si bilancia l'ossigeno con molecole di  $\text{H}_2\text{O}$  e l'idrogeno dell'acqua con ioni  $\text{OH}^-$  ( ambiente basico ), controllando il bilanciamento delle cariche:

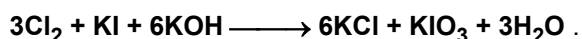


cariche: $-7 \longrightarrow -7$ cariche: $-6 \longrightarrow -6$
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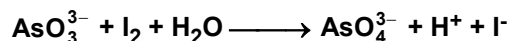
5) - Si somma membro a membro con le opportune semplificazioni:



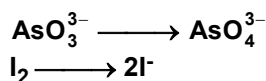
6) - Se richiesto si trasforma la reazione ionica netta in reazione molecolare bilanciata:



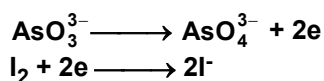
Lo stesso procedimento si utilizza in reazioni che avvengono in **ambiente neutro**:



1) - Si scrivono separatamente le semireazioni di ossidazione e di riduzione:

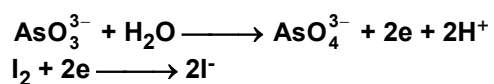


2) - Si bilanciano gli atomi e si indicano gli elettroni in movimento:

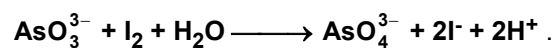
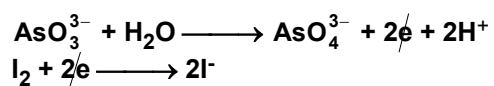


3) - Essendo uguale il numero degli elettroni in movimento non si deve effettuare alcun bilanciamento.

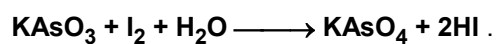
- 4) - Si bilancia nei reagenti l'ossigeno  $\text{H}_2\text{O}$  e nei prodotti l'idrogeno, così aggiunto, con ioni  $\text{H}^+$ , controllando il bilanciamento delle cariche:



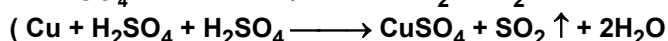
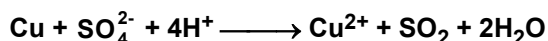
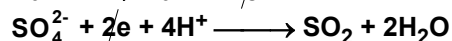
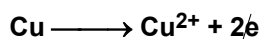
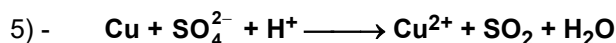
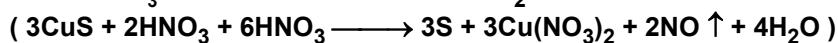
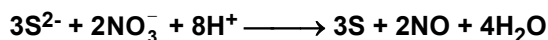
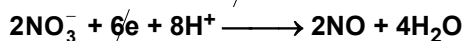
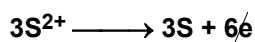
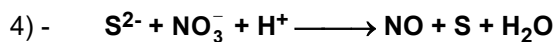
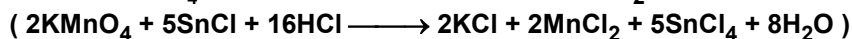
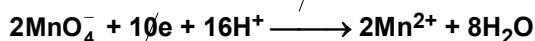
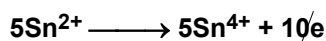
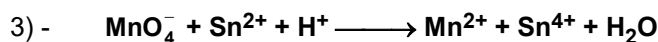
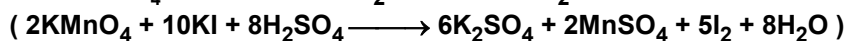
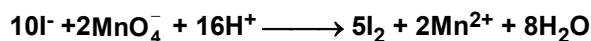
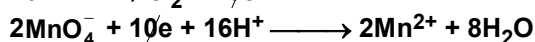
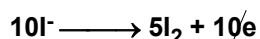
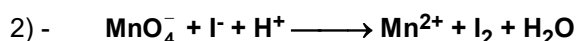
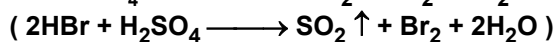
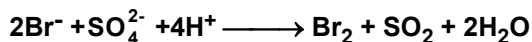
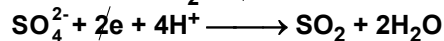
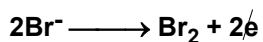
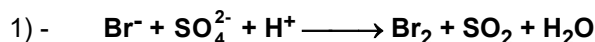
- 5) - Si somma membro a membro con le opportune semplificazioni:



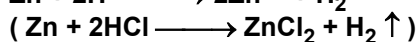
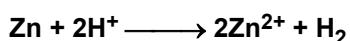
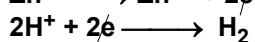
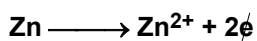
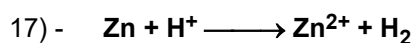
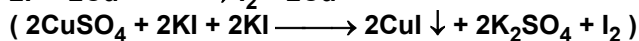
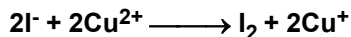
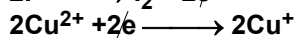
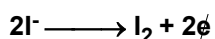
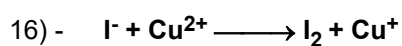
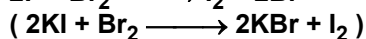
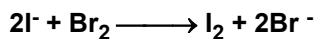
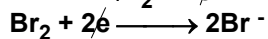
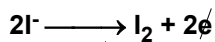
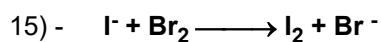
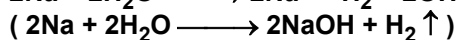
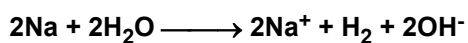
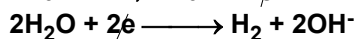
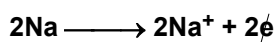
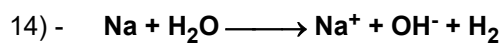
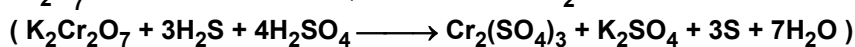
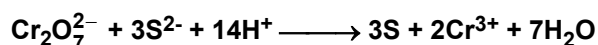
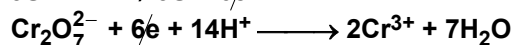
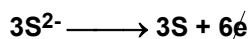
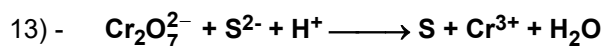
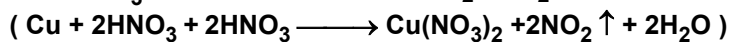
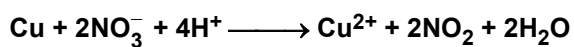
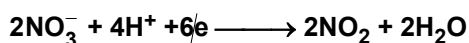
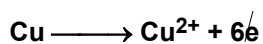
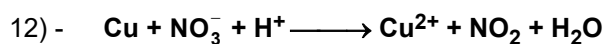
- 6) - Se richiesto si trasforma la reazione ionica netta in reazione molecolare bilanciata:

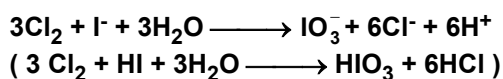
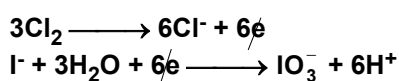
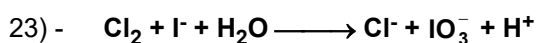
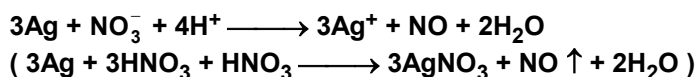
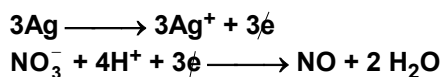
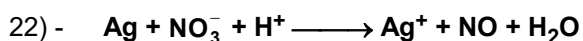
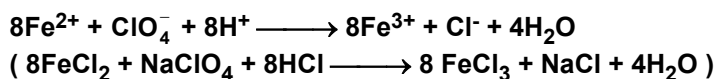
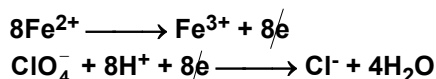
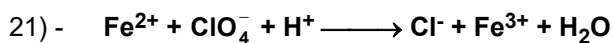
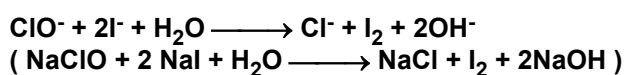
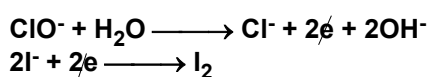
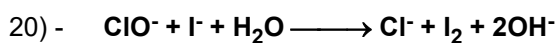
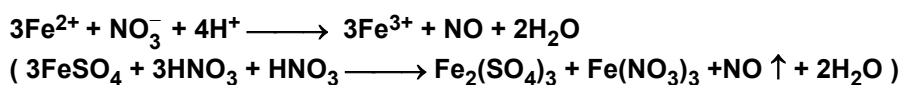
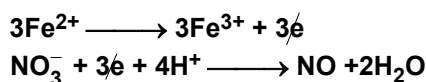
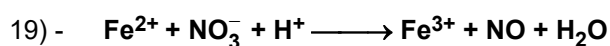
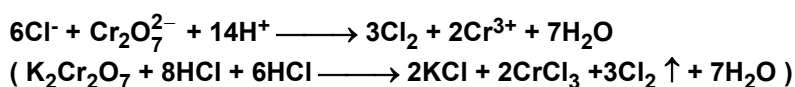
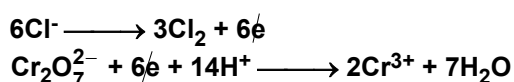
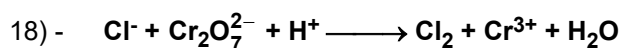


## Esempi di reazioni redox e loro bilanciamento

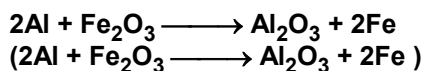
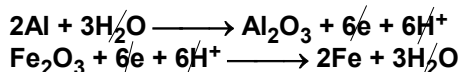
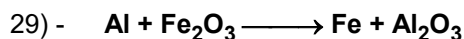
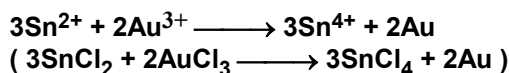
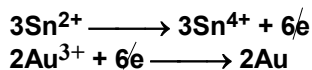
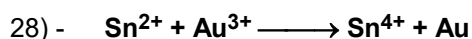
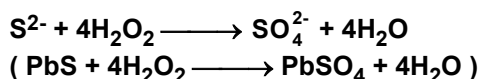
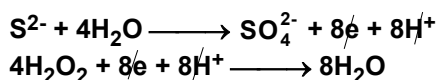
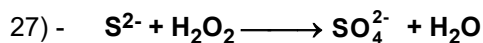
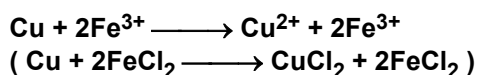
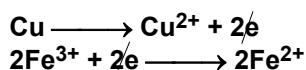
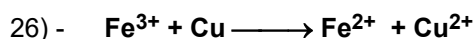
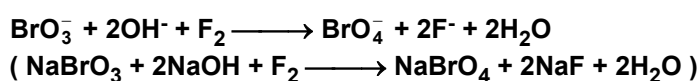
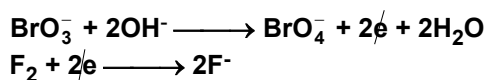
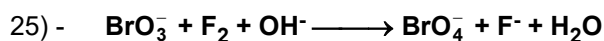
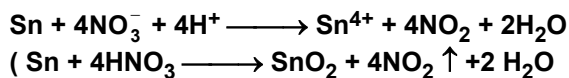
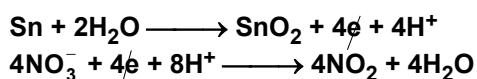
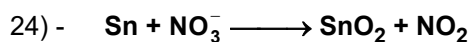


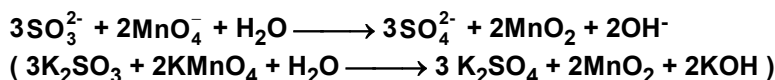
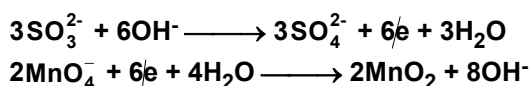
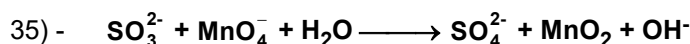
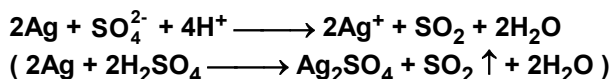
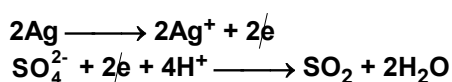
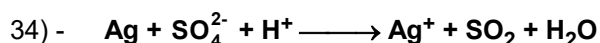
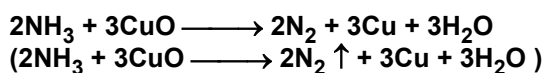
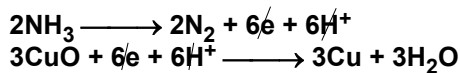
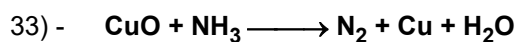
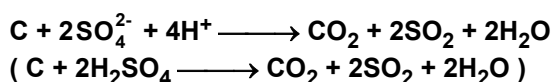
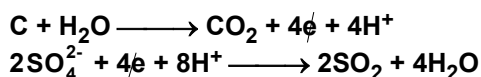
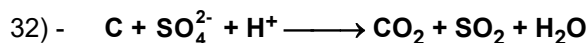
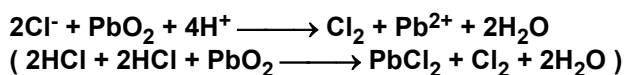
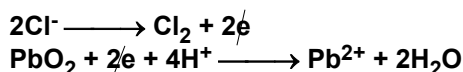
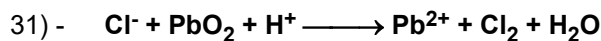
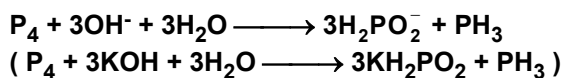
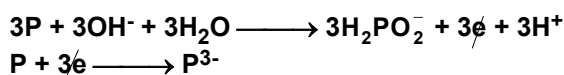
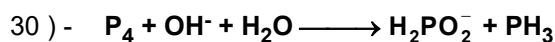
- 6) -  $\text{ClO}_3^- + \text{S}^{2-} \longrightarrow \text{SO}_4^{2-} + \text{Cl}^-$
- $$\begin{array}{l} 3\text{S}^{2-} + 12\text{H}_2\text{O} \longrightarrow 3\text{SO}_4^{2-} + 24\text{e}^- + 24\text{H}^+ \\ 4\text{ClO}_3^- + 24\text{e}^- + 24\text{H}^+ \longrightarrow 4\text{Cl}^- + 12\text{H}_2\text{O} \end{array}$$
- 
- $$\begin{array}{l} 3\text{S}^{2-} + 4\text{ClO}_3^- \longrightarrow 3\text{SO}_4^{2-} + 4\text{Cl}^- \\ (3\text{H}_2\text{S} + 4\text{HClO}_3 \longrightarrow 3\text{H}_2\text{SO}_4 + 4\text{HCl}) \end{array}$$
- 7) -  $\text{Hg} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Hg}^{2+} + \text{NO} + \text{H}_2\text{O}$
- $$\begin{array}{l} 3\text{Hg} \longrightarrow 3\text{Hg}^{2+} + 6\text{e}^- \\ 2\text{NO}_3^- + 6\text{e}^- + 8\text{H}^+ \longrightarrow 2\text{NO} + 4\text{H}_2\text{O} \end{array}$$
- 
- $$\begin{array}{l} 3\text{Hg} + 2\text{NO}_3^- + 8\text{H}^+ \longrightarrow 3\text{Hg}^{2+} + 2\text{NO} + 4\text{H}_2\text{O} \\ (3\text{Hg} + 2\text{HNO}_3 + 6\text{HCl} \longrightarrow 3\text{HgCl}_2 + 2\text{NO} \uparrow + 4\text{H}_2\text{O}) \end{array}$$
- 8) -  $\text{MnO}_4^- + \text{Cl}^- + \text{H}^+ \longrightarrow \text{Mn}^{2+} + \text{Cl}_2 + \text{H}_2\text{O}$
- $$\begin{array}{l} 10\text{Cl}^- \longrightarrow 5\text{Cl}_2 + 10\text{e}^- \\ 2\text{MnO}_4^- + 16\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 10\text{e}^- + 8\text{H}_2\text{O} \end{array}$$
- 
- $$\begin{array}{l} 10\text{Cl}^- + 2\text{MnO}_4^- + 16\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 5\text{Cl}_2 + 8\text{H}_2\text{O} \\ (2\text{KMnO}_4 + 10\text{HCl} + 6\text{HCl} \longrightarrow 2\text{MnCl}_2 + 2\text{KCl} + 5\text{Cl}_2 \uparrow + 8\text{H}_2\text{O}) \end{array}$$
- 9) -  $\text{Fe}^{2+} + \text{Cr}_2\text{O}_7^{2-} + \text{H}^+ \longrightarrow \text{Fe}^{3+} + \text{Cr}^{3+} + \text{H}_2\text{O}$
- $$\begin{array}{l} 6\text{Fe}^{2+} \longrightarrow 6\text{Fe}^{3+} + 6\text{e}^- \\ \text{Cr}_2\text{O}_7^{2-} + 6\text{e}^- + 14\text{H}^+ \longrightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} \end{array}$$
- 
- $$\begin{array}{l} 6\text{Fe}^{2+} + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ \longrightarrow 6\text{Fe}^{3+} + 2\text{Cr}^{3+} + 7\text{H}_2\text{O} \\ (6\text{FeSO}_4 + \text{K}_2\text{Cr}_2\text{O}_7 + 14\text{HNO}_3 \longrightarrow 2\text{Fe}_2(\text{SO}_4)_3 + 2\text{Fe}(\text{NO}_3)_2 + 2\text{KNO}_3 + 2\text{Cr}(\text{NO}_3)_3 + 7\text{H}_2\text{O}) \end{array}$$
- 10) -  $\text{MnO}_4^- + \text{H}_2\text{O}_2 \longrightarrow \text{Mn}^{2+} + \text{O}_2 + \text{H}_2\text{O}$
- $$\begin{array}{l} 5\text{H}_2\text{O}_2 \longrightarrow 5\text{O}_2 + 10\text{e}^- + 10\text{H}^+ \\ 2\text{MnO}_4^- + 10\text{e}^- + 16\text{H}^+ \longrightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} \end{array}$$
- 
- $$\begin{array}{l} 5\text{H}_2\text{O}_2 + 2\text{MnO}_4^- + 6\text{H}^+ \longrightarrow 5\text{O}_2 + 2\text{Mn}^{2+} + 8\text{H}_2\text{O} \\ (5\text{H}_2\text{O}_2 + 2\text{KMnO}_4 + 6\text{HCl} \longrightarrow 5\text{O}_2 \uparrow + 2\text{MnCl}_2 + 2\text{KCl} + 8\text{H}_2\text{O}) \end{array}$$
- 11) -  $\text{Cu} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Cu}^{2+} + \text{NO} + \text{H}_2\text{O}$
- $$\begin{array}{l} 3\text{Cu} \longrightarrow 3\text{Cu}^{2+} + 6\text{e}^- \\ 2\text{NO}_3^- + 8\text{H}^+ + 6\text{e}^- \longrightarrow 2\text{NO} + 4\text{H}_2\text{O} \end{array}$$
- 
- $$\begin{array}{l} 3\text{Cu} + 8\text{H}^+ \longrightarrow 3\text{Cu}^{2+} + 2\text{NO} + 4\text{H}_2\text{O} \\ (3\text{Cu} + 6\text{HNO}_3 + 2\text{HNO}_3 \longrightarrow 3\text{Cu}(\text{NO}_3)_2 + 2\text{NO} \uparrow + 4\text{H}_2\text{O}) \end{array}$$

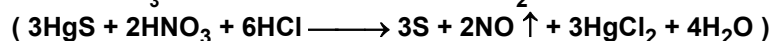
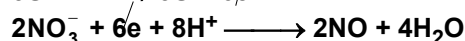
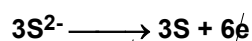
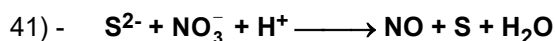
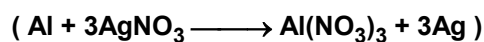
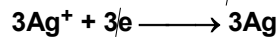
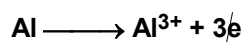
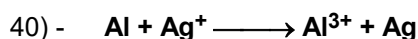
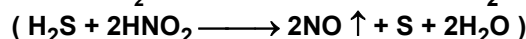
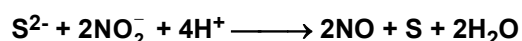
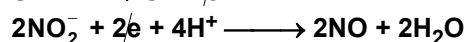
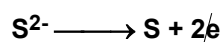
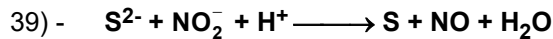
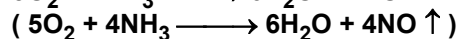
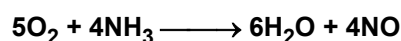
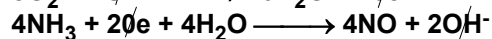
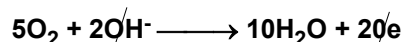
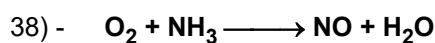
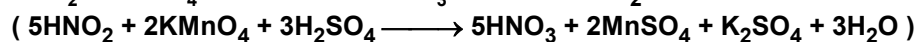
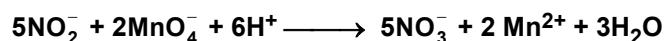
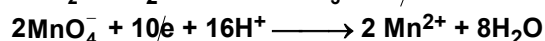
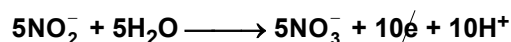
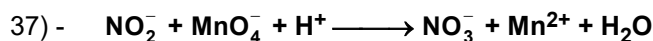
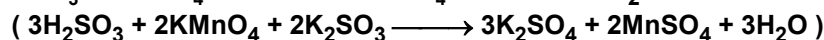
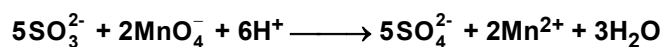
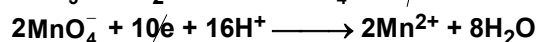
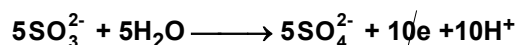
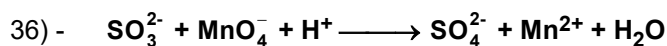


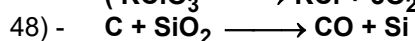
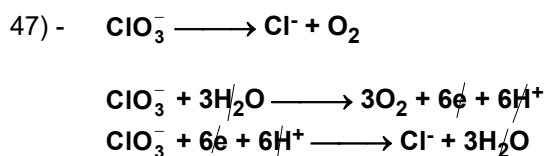
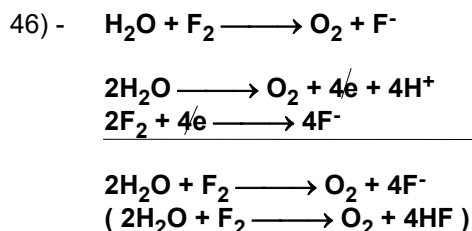
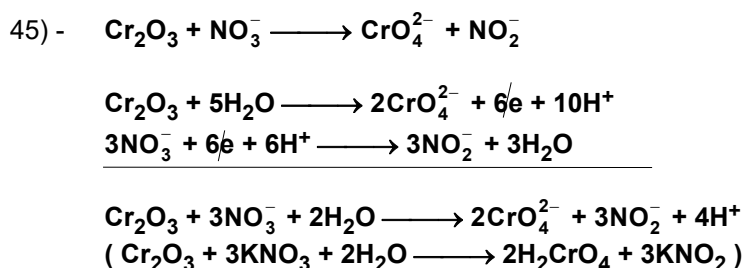
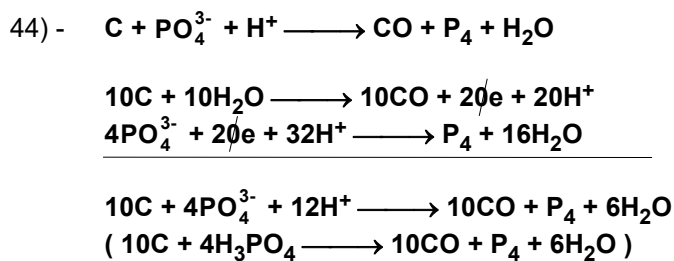
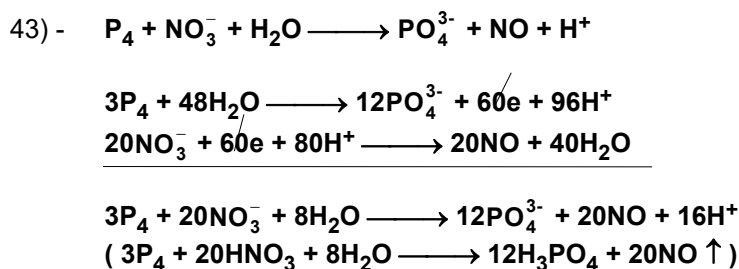
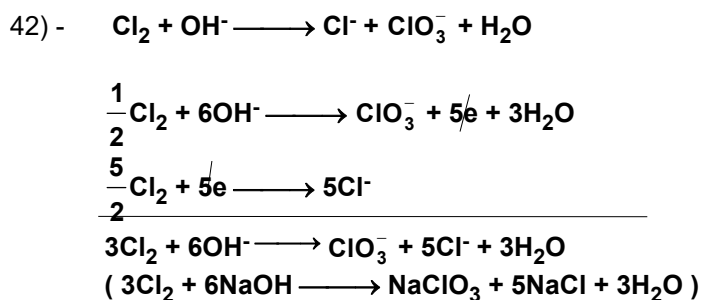


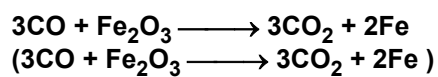
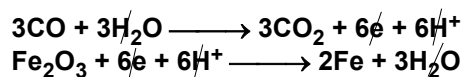
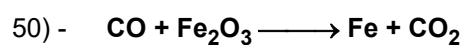
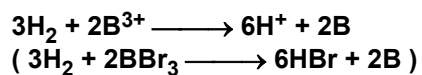
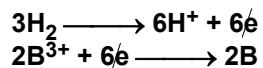
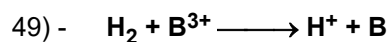
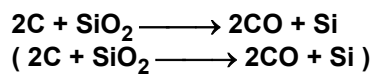
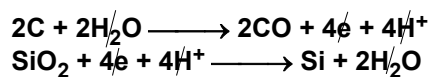












**Nota:** nelle semireazioni ioniche non sono indicati né i bilanciamenti parziali né i calcoli parziali degli elettroni. Il numero di elettroni indicato è quello risultante dal calcolo del m.c.m., come indicato nelle spiegazioni.

Le reazioni molecolari sono, in alcuni casi, solamente teoriche ed esemplificative.

## Riepilogo delle reazioni

- 1) -  $\text{Br}^- + \text{SO}_4^{2-} + \text{H}^+ \longrightarrow \text{Br}_2 + \text{SO}_2 + \text{H}_2\text{O}$
- 2) -  $\text{MnO}_4^- + \text{I}^- + \text{H}^+ \longrightarrow \text{Mn}^{2+} + \text{I}_2 + \text{H}_2\text{O}$
- 3) -  $\text{MnO}_4^- + \text{Sn}^{2+} + \text{H}^+ \longrightarrow \text{Mn}^{2+} + \text{Sn}^{4+} + \text{H}_2\text{O}$
- 4) -  $\text{S}^{2-} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{NO} + \text{S} + \text{H}_2\text{O}$
- 5) -  $\text{Cu} + \text{SO}_4^{2-} + \text{H}^+ \longrightarrow \text{Cu}^{2+} + \text{SO}_2 + \text{H}_2\text{O}$
- 6) -  $\text{ClO}_3^- + \text{S}^{2-} \longrightarrow \text{SO}_4^{2-} + \text{Cl}^-$
- 7) -  $\text{Hg} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Hg}^{2+} + \text{NO} + \text{H}_2\text{O}$
- 8) -  $\text{MnO}_4^- + \text{Cl}^- + \text{H}^+ \longrightarrow \text{Mn}^{2+} + \text{Cl}_2 + \text{H}_2\text{O}$
- 9) -  $\text{Fe}^{2+} + \text{Cr}_2\text{O}_7^{2-} + \text{H}^+ \longrightarrow \text{Fe}^{3+} + \text{Cr}^{3+} + \text{H}_2\text{O}$
- 10) -  $\text{MnO}_4^- + \text{H}_2\text{O}_2 \longrightarrow \text{Mn}^{2+} + \text{O}_2 + \text{H}_2\text{O}$
- 11) -  $\text{Cu} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Cu}^{2+} + \text{NO} + \text{H}_2\text{O}$
- 12) -  $\text{Cu} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Cu}^{2+} + \text{NO}_2 + \text{H}_2\text{O}$
- 13) -  $\text{Cr}_2\text{O}_7^{2-} + \text{S}^{2-} + \text{H}^+ \longrightarrow \text{S} + \text{Cr}^{3+} + \text{H}_2\text{O}$
- 14) -  $\text{Na} + \text{H}_2\text{O} \longrightarrow \text{Na}^+ + \text{OH}^- + \text{H}_2$
- 15) -  $\text{I}^- + \text{Br}_2 \longrightarrow \text{I}_2 + \text{Br}^-$
- 16) -  $\text{I}^- + \text{Cu}^{2+} \longrightarrow \text{I}_2 + \text{Cu}^+$
- 17) -  $\text{Zn} + \text{H}^+ \longrightarrow \text{Zn}^{2+} + \text{H}_2$
- 18) -  $\text{Cl}^- + \text{Cr}_2\text{O}_7^{2-} + \text{H}^+ \longrightarrow \text{Cl}_2 + \text{Cr}^{3+} + \text{H}_2\text{O}$
- 19) -  $\text{Fe}^{2+} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Fe}^{3+} + \text{NO} + \text{H}_2\text{O}$
- 20) -  $\text{ClO}^- + \text{I}^- + \text{H}_2\text{O} \longrightarrow \text{Cl}^- + \text{I}_2 + 2\text{OH}^-$
- 21) -  $\text{Fe}^{2+} + \text{ClO}_4^- + \text{H}^+ \longrightarrow \text{Cl}^- + \text{Fe}^{3+} + \text{H}_2\text{O}$
- 22) -  $\text{Ag} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{Ag}^+ + \text{NO} + \text{H}_2\text{O}$
- 23) -  $\text{Cl}_2 + \text{I}^- + \text{H}_2\text{O} \longrightarrow \text{Cl}^- + \text{IO}_3^- + \text{H}^+$
- 24) -  $\text{Sn} + \text{NO}_3^- \longrightarrow \text{SnO}_2 + \text{NO}_2$
- 25) -  $\text{BrO}_3^- + \text{F}_2 + \text{OH}^- \longrightarrow \text{BrO}_4^- + \text{F}^- + \text{H}_2\text{O}$
- 26) -  $\text{Fe}^{3+} + \text{Cu} \longrightarrow \text{Fe}^{2+} + \text{Cu}^{2+}$
- 27) -  $\text{S}^{2-} + \text{H}_2\text{O}_2 \longrightarrow \text{SO}_4^{2-} + \text{H}_2\text{O}$
- 28) -  $\text{Sn}^{2+} + \text{Au}^{3+} \longrightarrow \text{Sn}^{4+} + \text{Au}$
- 29) -  $\text{Al} + \text{Fe}_2\text{O}_3 \longrightarrow \text{Fe} + \text{Al}_2\text{O}_3$
- 30) -  $\text{P}_4 + \text{OH}^- + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{PO}_2^- + \text{PH}_3$
- 31) -  $\text{Cl}^- + \text{PbO}_2 + \text{H}^+ \longrightarrow \text{Pb}^{2+} + \text{Cl}_2 + \text{H}_2\text{O}$
- 32) -  $\text{C} + \text{SO}_4^{2-} + \text{H}^+ \longrightarrow \text{CO}_2 + \text{SO}_2 + \text{H}_2\text{O}$
- 33) -  $\text{CuO} + \text{NH}_3 \longrightarrow \text{N}_2 + \text{Cu} + \text{H}_2\text{O}$
- 34) -  $\text{Ag} + \text{SO}_4^{2-} + \text{H}^+ \longrightarrow \text{Ag}^+ + \text{SO}_2 + \text{H}_2\text{O}$
- 35) -  $\text{SO}_3^{2-} + \text{MnO}_4^- + \text{H}_2\text{O} \longrightarrow \text{SO}_4^{2-} + \text{MnO}_2 + \text{OH}^-$
- 36) -  $\text{SO}_3^{2-} + \text{MnO}_4^- + \text{H}^+ \longrightarrow \text{SO}_4^{2-} + \text{Mn}^{2+} + \text{H}_2\text{O}$
- 37) -  $\text{NO}_2^- + \text{MnO}_4^- + \text{H}^+ \longrightarrow \text{NO}_3^- + \text{Mn}^{2+} + \text{H}_2\text{O}$
- 38) -  $\text{O}_2 + \text{NH}_3 \longrightarrow \text{NO} + \text{H}_2\text{O}$
- 39) -  $\text{S}^{2-} + \text{NO}_2^- + \text{H}^+ \longrightarrow \text{S} + \text{NO} + \text{H}_2\text{O}$
- 40) -  $\text{Al} + \text{Ag}^+ \longrightarrow \text{Al}^{3+} + \text{Ag}$
- 41) -  $\text{S}^{2-} + \text{NO}_3^- + \text{H}^+ \longrightarrow \text{NO} + \text{S} + \text{H}_2\text{O}$
- 42) -  $\text{Cl}_2 + \text{OH}^- \longrightarrow \text{Cl}^- + \text{ClO}_3^- + \text{H}_2\text{O}$
- 43) -  $\text{P}_4 + \text{NO}_3^- + \text{H}_2\text{O} \longrightarrow \text{PO}_4^{3-} + \text{NO} + \text{H}^+$
- 44) -  $\text{C} + \text{PO}_4^{3-} + \text{H}^+ \longrightarrow \text{CO} + \text{P}_4 + \text{H}_2\text{O}$
- 45) -  $\text{Cr}_2\text{O}_3 + \text{NO}_3^- \longrightarrow \text{CrO}_4^{2-} + \text{NO}_2^-$
- 46) -  $\text{H}_2\text{O} + \text{F}_2 \longrightarrow \text{O}_2 + \text{F}^-$
- 47) -  $\text{ClO}_3^- \longrightarrow \text{Cl}^- + \text{O}_2$
- 48) -  $\text{C} + \text{SiO}_2 \longrightarrow \text{CO} + \text{Si}$
- 49) -  $\text{H}_2 + \text{B}^{3+} \longrightarrow \text{H}^+ + \text{B}$
- 50) -  $\text{CO} + \text{Fe}_2\text{O}_3 \longrightarrow \text{Fe} + \text{CO}_2$

## Tavola dei potenziali standard di riduzione ( a 25 °C )

E <sup>0</sup> ( volts )	reazione elettrodoica
+2.87	$F_2(g) + 2e \rightleftharpoons 2F^-(aq)$
+2.02	$S_2O_8^{2-}(aq) + 2e \rightleftharpoons 2SO_4^{2-}(aq)$
+1.77	$H_2O_2(aq) + 2H^+ + 2e \rightleftharpoons 2H_2O$
+1.70	$MnO_4^-(aq) + 4H^+(aq) + 3e \rightleftharpoons MnO_2(s) + 2H_2O$
+1.69	$PbO_2(s) + SO_4^{2-}(aq) + 4H^+ + 2e \rightleftharpoons PbSO_4(s) + 2H_2O$
+1.49	$MnO_4^-(aq) + 8H^+(aq) + 5e \rightleftharpoons Mn^{2+}(aq) + 4H_2O$
+1.45	$PbO_2(s) + 4H^+(aq) + 2e \rightleftharpoons Pb^{2+}(aq) + 2H_2O$
+1.44	$BrO_3^-(aq) + 6H^+(aq) + 6e \rightleftharpoons Br^-(aq) + 3H_2O$
+1.42	$Au^{3+}(aq) + 3e \rightleftharpoons Au(s)$
+1.36	$Cl_2(g) + 2e \rightleftharpoons 2Cl^-(aq)$
+1.33	$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O$
+1.23	$O_2(g) + 4H^+ + 4e \rightleftharpoons 2H_2O$
+1.20	$Pt^{2+}(aq) + 2e \rightleftharpoons Pt(s)$
+1.19	$IO_3^-(aq) + 6H^+(aq) + 5e \rightleftharpoons \frac{1}{2}I_2(s) + 9H_2O$
+1.07	$Br_2(aq) + 2e \rightleftharpoons 2Br^-(aq)$
+0.96	$NO_3^-(aq) + 4H^+(aq) + 3e \rightleftharpoons NO(g) + 2H_2O$
+0.90	$Hg^{2+}(aq) + 2e \rightleftharpoons Hg(s)$
+0.87	$NO_3^-(aq) + 4H^+(aq) + 2e \rightleftharpoons 2NO_2(g) + 2H_2O$
+0.80	$Ag^+(aq) + e \rightleftharpoons Ag(s)$
+0.77	$Fe^{3+}(aq) + e \rightleftharpoons Fe^{2+}(aq)$
+0.69	$O_2(g) + 2H^+(aq) + 2e \rightleftharpoons H_2O_2(aq)$
+0.53	$I_2(s) + 2e \rightleftharpoons 2I^-(aq)$
+0.45	$SO_2(aq) + 4H^+(aq) + 4e \rightleftharpoons S(s) + 2H_2O$
+0.401	$O_2(g) + 2H_2O + 4e \rightleftharpoons 4OH^-(aq)$
+0.34	$Cu^{2+}(aq) + 2e \rightleftharpoons Cu(s)$
+0.17	$SO_4^{2-}(aq) + 4H^+(aq) + 2e \rightleftharpoons H_2SO_3(aq) + H_2O$
+0.16	$Cu^{2+}(aq) + e \rightleftharpoons Cu^+(aq)$
+0.15	$Sn^{4+}(aq) + 2e \rightleftharpoons Sn^{2+}(aq)$
+0.14	$S(s) + 2H^+(aq) + 2e \rightleftharpoons H_2S(g)$
<b>+0.00</b>	<b><math>2H^+(aq) + 2e \rightleftharpoons H_2(g)</math></b>
-0.13	$Pb^{2+}(aq) + 2e \rightleftharpoons Pb(s)$
-0.14	$Sn^{2+}(aq) + 2e \rightleftharpoons Sn(s)$
-0.25	$Ni^{2+}(aq) + 2e \rightleftharpoons Ni(s)$
-0.28	$Co^{2+}(aq) + 2e \rightleftharpoons Co(s)$
-0.44	$Fe^{2+}(s) + 2e \rightleftharpoons Fe(s)$
-0.74	$Cr^{3+}(aq) + 3e \rightleftharpoons Cr(s)$
-0.76	$Zn^{2+}(aq) + 2e \rightleftharpoons Zn(s)$
-0.83	$2H_2O + 2e \rightleftharpoons H_2(g) + 2OH^-(aq)$
-1.19	$Mn^{2+}(aq) + 2e \rightleftharpoons Mn(s)$
-1.67	$Al^{3+}(aq) + 3e \rightleftharpoons Al(s)$
-2.37	$Mg^{2+}(aq) + 2e \rightleftharpoons Mg(s)$
-2.71	$Na^+(aq) + e \rightleftharpoons Na(s)$
-2.76	$Ca^{2+}(aq) + 2e \rightleftharpoons Ca(s)$
-2.89	$Sr^{2+}(aq) + 2e \rightleftharpoons Sr(s)$
-2.90	$Ba^{2+}(aq) + 2e \rightleftharpoons Ba(s)$
-2.92	$K^+(aq) + e \rightleftharpoons K(s)$
-3.04	$Li^+(aq) + e \rightleftharpoons Li(s)$