Redox Questions on oxidising and reducing agents

Table of standard electrode potentials for use in the questions below.

$Br_2(l) + 2e^- \rightleftharpoons 2Br^-(aq)$	$E^{\theta} = +1.09$ V
$Ce^{4+}(aq) + e^- \rightleftharpoons Ce^{3+}(aq)$	$E^{\theta} = +1.61$ V
$Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$	$E^{\theta} = -0.28$ V
$Co^{3+}(aq) + e^- \rightleftharpoons Co^{2+}(aq)$	$E^{\theta} = +1.82$ V
$Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr(s)$	$E^{\theta} = -0.74$ V
$Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)$	$E^{\theta} = -0.41$ V
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O(l)$	$E^{\theta} = +1.36$ V
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	$E^{\theta} = +0.34$ V
$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$	$E^{\theta} = +0.15$ V
$Cu^+(aq) + e^- \rightleftharpoons Cu(s)$	$E^{\theta} = +0.52$ V
$Eu^{3+}(aq) + e^- \rightleftharpoons Eu^{2+}(aq)$	$E^{\theta} = -0.43$ V
$F_2(g) + 2e^- \rightleftharpoons 2F^-(aq)$	$E^{\theta} = +2.87$ V
$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s)$	$E^{\theta} = -0.45$ V
$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq)$	$E^{\theta} = +0.77$ V
$Ho^{3+}(aq) + e^- \rightleftharpoons Ho(s)$	$E^{\theta} = -2.32$ V
$PbO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Pb^{2+}(aq) + 2H_2O(l)$	$E^{\theta} = +1.46$ V
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	$E^{\theta} = +0.54$ V
$2IO_3^-(aq) + 12H^+(aq) + 10e^- \rightleftharpoons I_2(s) + 6H_2O(l)$	$E^{\theta} = +1.19$ V
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$	$E^{\theta} = +1.51$ V
$Na^+(aq) + e^- \rightleftharpoons Na(s)$	$E^{\theta} = -2.71$ V
$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$	$E^{\theta} = +0.80$ V
$Pu^{4+}(aq) + e^- \rightleftharpoons Pu^{3+}(aq)$	$E^{\theta} = +0.97$ V
$Pu^{3+}(aq) + 3e^- \rightleftharpoons Pu(s)$	$E^{\theta} = -2.03$ V
$U^{4+}(aq) + e^- \rightleftharpoons U^{3+}(aq)$	$E^{\theta} = -0.61$ V
$U^{3+}(aq) + 3e^- \rightleftharpoons U(s)$	$E^{\theta} = -1.79$ V
$UO^{2+}(aq) + 4H^+(aq) + 2e^- \rightleftharpoons U^{4+}(aq) + 2H_2O(l)$	$E^{\theta} = +0.33$ V

Redox Questions on oxidising and reducing agents

1 Which is the strongest oxidising agent in this table? ………F_2……………..

Not Na^+

2 Which is the strongest reducing agent in this table? ………Na…………………

3 State whether each of the following is TRUE or FALSE

Ce^{4+} has a more positive E$^\ominus$ value

(a) Ce^{4+} is a stronger oxidising agent than Br_2 — **TRUE** or FALSE

(b) Co is a stronger reducing agent than Cr — TRUE or **FALSE**

Looking at the oxidation reaction (reverse reaction) – the potential is more positive for Cr

(c) Cr^{2+} is a stronger reducing agent than Co^{2+} — **TRUE** or FALSE

Looking at the oxidation reaction $M^{2+} \rightarrow M^{3+} + e^-$

(d) Pu will reduce Cr^{2+} to Cr — **TRUE** or FALSE

(e) MnO_4^-/H^+ will oxidise Pu^{3+} to Pu^{4+} — **TRUE** or FALSE

Pu has a more negative E$^\ominus$ value, therefore is a stronger reducing agent than Cr

(f) Ce^{4+} will oxidise F^- to F_2 — TRUE or **FALSE**

(g) Br_2 is a stronger oxidising agent than Pu^{4+} — **TRUE** or FALSE

4 Deduce whether each of the following reactions will be spontaneous or not

(a) $2Cr^{2+}(aq) + I_2(s) \rightarrow 2Cr^{3+}(aq) + 2I^-(aq)$ — **SPONTANEOUS** or NOT SPONTANEOUS

+0.41V

$2Cr^{2+}(aq) + I_2(s) \rightarrow 2Cr^{3+}(aq) + 2I^-(aq)$ E$^\ominus_{cell}$= +0.93 V positive, therefore spontaneous

+0.54 V

(b) $Pu(s) + Ho^{3+}(aq) \rightarrow Pu^{3+}(aq) + Ho(s)$ — SPONTANEOUS or **NOT SPONTANEOUS**

+2.03 V

$Pu(s) + Ho^{3+}(aq) \rightarrow Pu^{3+}(aq) + Ho(s)$ E$^\ominus_{cell}$= -0.29 V negative, therefore not spontaneous

-2.32 V

(c) $MnO_4^-(aq) + 8H^+(aq) + 5Fe^{3+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{2+}(aq)$

SPONTANEOUS or **NOT SPONTANEOUS**

reduction

$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{3+}(aq) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Fe^{2+}(aq)$

reduction

Value between -1.51 V and -1.36 V for the oxidation reaction (Pb^{2+} to PbO_2)

Both half-reactions involve reduction, therefore this cannot be spontaneous.

5 (a) Identify a species that can be oxidised by MnO_4^-/H^+ but not by $Cr_2O_7^{2-}/H^+$………Pb^{2+}………..

(b) Identify a species that will oxidise Fe^{2+} to Fe^{3+} but not Pu^{3+} to Pu^{4+}…….Ag^+…………..

E$^\ominus$ value between +0.77 V and +0.97 V. Must be Ag^+, not Ag – Ag^+ is the oxidising agent

6 (a) By considering the following electrode potentials

$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$ $E^\theta = +0.34$ V

$Cu^{2+}(aq) + e^- \rightleftharpoons Cu^+(aq)$ $E^\theta = +0.15$ V

$Cu^+(aq) + e^- \rightleftharpoons Cu(s)$ $E^\theta = +0.52$ V

deduce what will happen to Cu^+ ions in solution – write an equation.

Cu^+ ions will be oxidised to Cu^{2+} and reduced to Cu

The same species is oxidised and reduced – a *disproportionation* reaction

$Cu^+(aq) \rightarrow Cu^{2+}(aq) + e^-$ $E^\theta_{ox} = -0.15$ V

Potential for oxidation

$Cu^+(aq) + e^- \rightarrow Cu(s)$ $E^\theta = +0.52$ V

Overall reaction: $2Cu^+(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$ $E^\theta_{cell} = +0.37$ V

Positive value, therefore spontaneous.

(b) Deduce whether $U^{3+}(aq)$ do a similar reaction to the reaction in (a)

Need to multiply this half-equation by 3 to balance the electrons when writing the overall redox equation

$U^{3+}(aq) \rightarrow U^{4+}(aq) + e^-$ $E^\theta = +0.61$ V

$U^{3+}(aq) + 3e^- \rightarrow U(s)$ $E^\theta = -1.79$ V

Overall reaction: $4U^{3+}(aq) \rightarrow 3U^{4+}(aq) + U(s)$ $E^\theta_{cell} = -1.18$ V

U^{3+} will not undergo a similar reaction (will not disproportionate) because the cell potential is negative – the reaction shown is not spontaneous.

7 Deduce an equation for a spontaneous reaction involving Ag.

The only possibility using the half equations given in the table is the oxidation of Ag to Ag^+:

$Ag(s) \rightarrow Ag^+(aq) + e^-$ E = -0.80 V

Anything with a standard electrode potential more positive than 0.80 V will oxidise Ag to Ag^+, so there are several possibilities:

Br_2, Ce^{4+}, Co^{3+}, $Cr_2O_7^{2-}$, F_2, PbO_2, IO_3^-, MnO_4^-, Pu^{4+}

Balanced equations:

$Br_2(l) + 2Ag(s) \rightarrow 2Br^-(aq) + 2Ag^+(aq)$
$Ce^{4+}(aq) + Ag(s) \rightarrow Ce^{3+}(aq) + Ag^+(aq)$
$Co^{3+}(aq) + Ag(s) \rightarrow Co^{2+}(aq) + Ag^+(aq)$
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6Ag(s) \rightarrow 2Cr^{3+}(aq) + 7H_2O(l) + 6Ag^+(aq)$
$F_2(g) + 2Ag(s) \rightarrow 2F^-(aq) + 2Ag^+(aq)$
$PbO_2(s) + 4H^+(aq) + 2Ag(s) \rightarrow Pb^{2+}(aq) + 2H_2O(l) + 2Ag^+(aq)$
$2IO_3^-(aq) + 12H^+(aq) + 10Ag(s) \rightarrow I_2(s) + 6H_2O(l) + 10Ag^+(aq)$
$MnO_4^-(aq) + 8H^+(aq) + 5Ag(s) \rightarrow Mn^{2+}(aq) + 4H_2O(l) + 5Ag^+(aq)$
$Pu^{4+}(aq) + Ag(s) \rightarrow Pu^{3+}(aq) + Ag^+(aq)$