$S^\ominus H_2$ 130.7

$S^\ominus H^+$ 0

Table 1 Thermodynamic data at 298.15 K for unknown metal, M, and one of its cations.

Substance	State	$\Delta H_f^\ominus$ / kJ mol^{-1}	$\Delta G_f^\ominus$ / kJ mol^{-1}	$S^\ominus$ / JK^{-1} mol^{-1}
M	s	0	0	28.3
M^{3+}	aq	−531.0		−321.7

(a) Write down the formation reaction for aqueous M^{3+} ions. Calculate the value of $\Delta G_f^\ominus$ (M^{3+}, aq) at 298.15 K. Use this calculated value to identify the position that M would have in Table 12.1 of Book 4. Finally, identify M.

Formation reaction :- $M + 3H^+ = M^{3+} + 1.5\,H_2(g)$

Formula :- $\Delta G_f^\ominus = \Delta H_f^\ominus - T\Delta S_f^\ominus$

Then convert $S^\ominus$ into $S_f^\ominus$

$= S^\ominus(M^{3+}) - \frac{1}{2}S^\ominus(H_2) - S^\ominus(M) - 3S^\ominus(H^+)$

$= -321.7 - \frac{1}{2} \times 130.7 - 28.3$

$= -415.3\ J\,K^{-1}\,mol^{-1}$

$\Delta H_f^\ominus = -531.0\ kJ\,mol^{-1}$

$\Delta G_f^\ominus = (298.15\ K) \times (-415.3\ J\,K\,mol^{-1}) = -12820\ J\,mol^{-1}$

$\Delta G_f^\ominus = -415.3\ kJ\,mol^{-1} + 12820\ J\,mol^{-1}$

$= 415.3\ kJ\,mol^{-1} + 12.8\ kJ\,mol^{-1}$

$= -402.5\ kJ\,mol^{-1}$