Answers to Exercise 7.1
Activities and Reaction Quotients

1.

(a) The species in solution are $Na^{+}_{(aq)}$, $Cl^{-}_{(aq)}$ and water.

This is a very dilute solution, so it is reasonable to treat water as a "liquid" (rather than as a "solvent"), giving it an activity of 1.

The activities of the ions have to be calculated from their concentrations.

Step 1: Calculate the moles of $NaCl$ from the mass and molar mass

$$75\ mg\ NaCl \times \frac{1\ g}{1000\ mg} \times \frac{1\ mol}{58.4425\ g} = 0.0013\ mol\ NaCl$$

Step 2: Use mole ratio to calculate the moles of each ion

Each mole of $NaCl$ dissociates into $1\ mol\ Na^{+}$ and $1\ mol\ Cl^{-}$.

$$n_{Na^+} = 0.0013\ mol\ NaCl \times \frac{1\ mol\ Na^{+}}{1\ mol\ NaCl} = 0.0013\ mol\ Na^{+}$$

$$n_{Cl^-} = 0.0013\ mol\ NaCl \times \frac{1\ mol\ Cl^{-}}{1\ mol\ NaCl} = 0.0013\ mol\ Cl^{-}$$

Step 3: Divide moles of each ion by the volume of the solution to get molarity

$$M_{Na^+} = \frac{0.0013\ mol\ Na^{+}}{1.000\ L} = 0.0013\ \frac{mol\ Na^{+}}{L}$$

$$M_{Cl^-} = \frac{0.0013\ mol\ Cl^{-}}{1.000\ L} = 0.0013\ \frac{mol\ Cl^{-}}{L}$$

Step 4: Divide molarity of each ion by 1 M to give activity of a solute

$$a_{Na^+} = \frac{0.0013\ \frac{mol}{L}}{1\ \frac{mol}{L}} = 0.0013$$

$$a_{Cl^-} = \frac{0.0013\ \frac{mol}{L}}{1\ \frac{mol}{L}} = 0.0013$$

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

(b) The species in solution are $Cu^{2+}_{(aq)}$, $NO^{-}_{3(aq)}$ and water.

This is a very dilute solution, so it is reasonable to treat water as a "liquid" (rather than as a "solvent"), giving it an activity of 1.

The activities of the ions have to be calculated from their concentrations.

Step 1: Calculate the moles of $Cu(NO_3)_2$ from the mass and molar mass

$$75\ mg\ Cu(NO_3)_2 \times \frac{1\ g}{1000\ mg} \times \frac{1\ mol}{187.5558\ g} = 0.00040\ mol\ Cu(NO_3)_2$$

Step 2: Use mole ratio to calculate the moles of each ion

Each mole of $Cu(NO_3)_2$ dissociates into 1 $mol\ Cu^{2+}$ and 2 $mol\ NO_3^-$.

$$n_{Cu^{2+}} = 0.00040\ mol\ Cu(NO_3)_2 \times \frac{1\ mol\ Cu^{2+}}{1\ mol\ Cu(NO_3)_2} = 0.00040\ mol\ Cu^{2+}$$

$$n_{NO_3^-} = 0.00040\ mol\ Cu(NO_3)_2 \times \frac{1\ mol\ NO_3^-}{1\ mol\ Cu(NO_3)_2} = 0.00080\ mol\ NO_3^-$$

Step 3: Divide moles of each ion by the volume of the solution to get molarity

$$M_{Cu^{2+}} = \frac{0.00040\ mol\ Cu^{2+}}{1.000\ L} = 0.00040\ \frac{mol\ Cu^{2+}}{L}$$

$$M_{NO_3^-} = \frac{0.00080\ mol\ NO_3^-}{1.000\ L} = 0.00080\ \frac{mol\ NO_3^-}{L}$$

Step 4: Divide molarity of each ion by 1 M to give activity of a solute

$$a_{Cu^{2+}} = \frac{0.00040\frac{mol}{L}}{1\frac{mol}{L}} = 0.00040$$

$$a_{NO_3^-} = \frac{0.00080\frac{mol}{L}}{1\frac{mol}{L}} = 0.00080$$

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

(c) The species in solution are ethanol and water. Neither is a pure liquid, so it is necessary to calculate the mole fraction of each species.

Step 1: Calculate the mass of each species

$$65\ ml\ CH_3CH_2OH \times 0.789\frac{g}{mL} = 51\ g\ CH_3CH_2OH$$

$$35\ ml\ H_2O \times 0.998\frac{g}{mL} = 35\ g\ H_2O$$

Step 2: Calculate the moles of each species

$$51\ g\ CH_3CH_2OH \times \frac{1\ mol}{46.0688\ g} = 1.1\ mol\ CH_3CH_2OH$$

$$35\ g\ H_2O \times \frac{1\ mol}{18.0152\ g} = 1.9\ mol\ H_2O$$

Step 3: Calculate the mole fraction of each species

$$X_{CH_3CH_2OH} = \frac{n_{CH_3CH_2OH}}{n_{CH_3CH_2OH}+n_{H_2O}} = \frac{1.1\ mol}{1.1\ mol+1.9\ mol} = 0.36$$

$$X_{H_2O} = \frac{n_{H_2O}}{n_{H_2O}+n_{CH_3CH_2OH}} = \frac{1.9\ mol}{1.9\ mol+1.1\ mol} = 0.64$$

Step 4: Calculate the activity of each species

$$a_{CH_3CH_2OH} = X_{CH_3CH_2OH} = 0.36$$

$$a_{H_2O} = X_{H_2O} = 0.64$$

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?

The two mole fractions add up to 1 – as they should.

2.

(a) $Q = \frac{a_{C_6H_{12}}}{(a_{C_6H_{10}})(a_{H_2})}$

(b) The palladium catalyst is a solid, so its activity is 1. Doubling the amount of palladium catalyst would not change its activity *and* the activity of palladium does not appear in the reaction quotient expression, so doubling the amount of palladium would have no impact on the reaction quotient for this reaction.

(c)

i. Before the reaction starts, $a_{C_6H_{12}} = 0$ because there is no C_6H_{10} since none has been produced yet. Therefore, $Q = 0$

ii. The activity of hydrogen gas is being held constant: $a_{H_2} = \frac{1\ bar}{1\ bar} = 1$.

Before you can calculate the activities of the cyclohexane and cyclohexene, you have to use stoichiometry to calculate how many moles of each are in the flask.

Step 1: Organize your information to calculate the moles of C_6H_{10} and C_6H_{12}

	C_6H_{10}	+	H_2	→	C_6H_{10}
$n_{initial}$	0.125 mol		excess		0 mol
n_{change}	-0.050 mol		-0.050 mol		+0.050 mol
n_{final}	0.075 mol		n/a		0.050 mol

Step 2: Calculate the molarity of C_6H_{10} and C_6H_{12}

$M_{C_6H_{10}} = \frac{0.075\ mol}{0.250\ L} = 0.30\ \frac{mol}{L}$

$M_{C_6H_{12}} = \frac{0.050\ mol}{0.250\ L} = 0.20\ \frac{mol}{L}$

Step 3: Calculate the activity of each species

$a_{C_6H_{10}} = \frac{M_{C_6H_{10}}}{1\ M} = \frac{0.30\ M}{1\ M} = 0.30$

$a_{C_6H_{12}} = \frac{M_{C_6H_{12}}}{1\ M} = \frac{0.20\ M}{1\ M} = 0.20$

Step 4: Calculate reaction quotient from activities

$Q = \frac{a_{C_6H_{12}}}{(a_{C_6H_{10}})(a_{H_2})} = \frac{0.20}{(0.30)(1)} = 0.67$

Step 5: Check your work

Does your answer seem reasonable? Are sig. fig. correct?