$$\frac{\overrightarrow{\vdash v_k : (\mathbf{Value}\ k)} \qquad \overrightarrow{\vdash v_v : \tau_v} \qquad p = \{\overrightarrow{(k,\ \tau_v)}\}}{\vdash \{\overrightarrow{(v_k\ v_v)}\} : (\mathbf{HMap}^{\mathcal{C}}\ p)\ ;\ \mathtt{tt}|\mathtt{ff}\ ;\ \emptyset}\ \text{T-HMAP}$$

$$\Gamma \vdash k : (\mathbf{Value}\ k)\ ;\ \mathtt{tt}|\mathtt{ff}\ ;\ \emptyset\ \text{T-KW}$$

$$\frac{\Gamma \vdash e_m : (\bigcup\ \overrightarrow{(\mathbf{HMap}^{\mathcal{A}}\ p\ a)}^{i})\ ;\ \psi_+|\psi_-\ ;\ o \qquad \Gamma \vdash e_k : (\mathbf{Value}\ k) \qquad \overrightarrow{(k\ \tau) \in p}^{i}}{\Gamma \vdash (\text{get}\ e_m\ e_k) : (\bigcup\ \overrightarrow{\tau}^{i})\ ;\ \mathtt{tt}|\mathtt{tt}\ ;\ \mathbf{key}_k(x)[o/x]}\ \text{T-GETHMAP}$$

$$\frac{\Gamma \vdash e_m : (\mathbf{HMap}^{\mathcal{A}}\ p\ a)\ ;\ \psi_+|\psi_-\ ;\ o \qquad \Gamma \vdash e_k : (\mathbf{Value}\ k) \qquad k \in a}{\Gamma \vdash (\text{get}\ e_m\ e_k) : \mathbf{nil}\ ;\ \mathtt{tt}|\mathtt{tt}\ ;\ \mathbf{key}_k(x)[o/x]}\ \text{T-GETHMAPABSENT}$$

$$\frac{\Gamma \vdash e_m : (\mathbf{HMap}^{\mathcal{P}}\ p\ a)\ ;\ \psi_+|\psi_-\ ;\ o \qquad \Gamma \vdash e_k : (\mathbf{Value}\ k) \qquad (k\ \tau) \notin p \qquad k \notin a}{\Gamma \vdash (\text{get}\ e_m\ e_k) : \top\ ;\ \mathtt{tt}|\mathtt{tt}\ ;\ \mathbf{key}_k(x)[o/x]}\ \text{T-GETHMAPPARTIALDEFAULT}$$

$$\frac{\Gamma \vdash e_m : (\mathbf{HMap}^{\mathcal{A}}\ p\ a) \qquad \Gamma \vdash e_k : (\mathbf{Value}\ k) \qquad \Gamma \vdash e_v : \tau \qquad k \notin a}{\Gamma \vdash (\text{assoc}\ e_m\ e_k\ e_v) : (\mathbf{HMap}^{\mathcal{A}}(p, (k\ \tau))\ a)\ ;\ \mathtt{tt}|\mathtt{ff}\ ;\ \emptyset}\ \text{T-ASSOCHMAP}$$

Figure 5. Map Typing Rules

$$\frac{\Sigma(x) = \gamma}{\Sigma \vdash x : \gamma}\ \text{TA-LOCAL} \qquad \Sigma \vdash \mathsf{nil} : ?\ \text{TA-NIL} \qquad \Sigma \vdash \mathsf{true} : \mathbf{Boolean}\ \text{TA-TRUE} \qquad \Sigma \vdash \mathsf{false} : \mathbf{Boolean}\ \text{TA-FALSE}$$

$$\Sigma \vdash k : \mathbf{Keyword}\ \text{TA-KW} \qquad \Sigma \vdash C : \mathbf{Class}\ \text{TA-CLASS}$$

$$\Sigma \vdash (\text{new}_{[[\overrightarrow{C_i}], C_1]}\ C\ \overrightarrow{e}) : C_1\ \text{TA-NEWSTATIC} \qquad \Sigma \vdash (\text{new}\ C\ \overrightarrow{e}) : ?\ \text{TA-NEWREFL} \qquad \Sigma \vdash \lambda x^{\tau}.e : ?\ \text{TA-ABS}$$

$$\frac{\Sigma, x : C \vdash e : \gamma}{\Sigma \vdash (\text{let}\ [\hat{}C\ x\ e_1]\ e) : \gamma}\ \text{TA-LETHINT} \qquad \frac{\Sigma \vdash e_1 : \gamma_1 \qquad \Sigma, x : \gamma_1 \vdash e : \gamma}{\Sigma \vdash (\text{let}\ [x\ e_1]\ e) : \gamma}\ \text{TA-LET}$$

$$\Sigma \vdash (.\ e\ fld) : ?\ \text{TA-FIELDREFL} \qquad \Sigma \vdash (.\ e\ fld_{C}^{C_1}) : C\ \text{TA-FIELDSTATIC} \qquad \Sigma \vdash (.\ e\ (mth\ \overrightarrow{e_i})) : ?\ \text{TA-METHODREFL}$$

$$\Sigma \vdash (.\ e\ (mth_{[[\overrightarrow{C_i}], C]}^{C_1}\ \overrightarrow{e_i})) : C\ \text{TA-METHODSTATIC} \qquad \Sigma \vdash (e\ e') : ?\ \text{TA-APP}$$

$$\frac{\Sigma(x) = \gamma}{\Sigma \vdash (x\ e') : \gamma}\ \text{TA-APPLOCAL} \qquad \frac{\Sigma \vdash e : \gamma}{\Sigma \vdash (\text{do}\ e_1\ e) : \gamma}\ \text{TA-DO} \qquad \Sigma \vdash (\text{defmulti}\ \tau\ e) : ?\ \text{TA-DEFMULTI}$$

$$\Sigma \vdash (\text{defmethod}\ e_1\ e_2\ e_3) : ?\ \text{TA-DEFMETHOD} \qquad \frac{\Sigma \vdash e_2 : C \qquad \Sigma \vdash e_3 : C}{\Sigma \vdash (\text{if}\ e_1\ e_2\ e_3) : C}\ \text{TA-IF}$$

$$\Sigma \vdash (\text{if}\ e_1\ e_2\ e_3) : ?\ \text{TA-IFUNKNOWN} \qquad \Sigma \vdash (\text{isa?}\ e\ e) : \mathbf{Boolean}\ \text{TA-ISA} \qquad \Sigma \vdash c : ?\ \text{TA-CONST}$$

Figure 6. tools.analyzer Type Hints