a) $S(x)$: x's statement — Constants: a, b, c, v — $D = \{Arthur, Bertram, Carleton, Victor\}$

$friend(x,y)$: x is y's friend — $\phi(a) = Arthur$ $\phi(b) = Bertram$ $\phi(c) = Carleton$ $\phi(v) = Victor$

$inTown(x)$: x is intown — $answer(X)$: X is the murderer

$know(x,y)$: x knows y

① $S(a) \rightarrow friend(b,v) \wedge \neg friend(c,v)$

② $S(b) \rightarrow \neg intown(b) \wedge \neg know(b,v)$

③ $S(c) \rightarrow intown(b) \wedge intown(A)$

④ $\Sigma x.\Sigma y.\ friend(X,Y) \rightarrow know(X,Y)$

⑤ $\Sigma x.\Sigma y.\Sigma z.\ \neg S(x) \rightarrow S(y) \wedge S(z)$

b) CF:

① $\neg S(a), friend(b,v)$

② $\neg S(a), \neg friend(c,v)$

③ $\neg S(b), \neg intown(b)$

④ $\neg S(b), \neg know(b,v)$

⑤ $\neg S(c), intown(b)$

⑥ $\neg S(c), intown(A)$

⑦ $\neg friend(f(x), g(y)), know(f(x), g(y))$

⑧ $S(h(x)), S(i(y))$

⑨ $S(h(x)), S(j(z))$

⑩ $S(M), Answer(M)$

c) 11 $[1_b, 7_a]\{f(x)=b, g(x)=v\}(\neg S(a), know(b,v))$

12 $[11_b, 4_b](\neg S(a), \neg S(b))$

13 $[12_a, 9_a]\{h(x)=a\}(\neg S(b), S(i(y)))$

14 $[13_b, 5_a]\{i(x)=c\}(\neg S(b), intown(b))$

15 $[14_b, 3_b](\neg S(b))$

16 $(15_a, 10_a)\{M=b\}$ (Answer (b))

d)

1 $\neg S(a), friend(b,v)$

2 $\neg S(a), \neg friend(c,v)$

3 $\neg S(b), \neg intown(b)$

4 $\neg S(b), \neg know(b,v)$

5 $\neg S(c), intown(b)$

6 $\neg S(c), intown(A)$

7 $\neg friend(f(x),g(y)), know(f(x),g(y))$

8 $S(h(x)), \neg S(i(y))$

9 $S(h(x)), S(j(z))$

10 $S(M_1), S(M_2), Answer(M_1, M_2)$

11 $[1b, 7a]\{f(x)=b, g(x)=v\}(\neg S(a), know(b,v))$

12 $[11b, 4b](\neg S(a), \neg S(b))$

13 $[12b, 8a]\{h(x)=b\}(\neg S(a), S(i(y)))$

14 $[13b, 5a]\{i(y)=c\}(\neg S(a), \neg S(c))$

15 $[14a, 9a]\{h(x)=b, j(z)=a\}(\neg S(c), S(b))$

16 $[15b, 4a](\neg S(c), \neg know(b,v))$

17 $[16b, 7b]\{f(x)=b, g(x)=v\}(\neg S(c), \neg friend(b,v))$

18 $[17b, 1b](\neg S(c), \neg S(a))$

19 $[18ab, 10ab]\{M_1=a, M_2=c\}(Answer(a,c))$