Electronic Supplementary Material (ESI) for Nanoscale.

Supplementary Material

Scalable Synthesis of Ternary Nanocatalysts for High Efficiency Electrooxidation Catalysis by Microfluidics

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Supplementary Figures

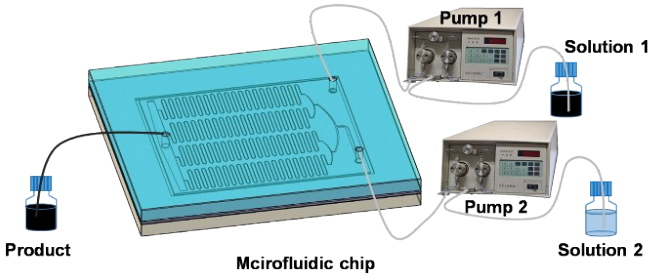

Fig. S1. The schematic illustration of microfluidic synthesis system.

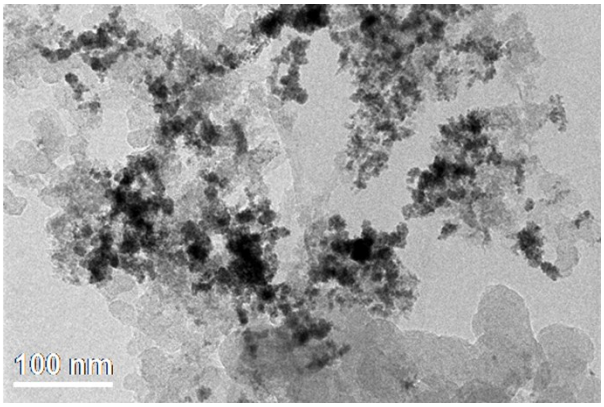

Fig. S2. TEM image of PtFeCu/C-H_2O with the pump flow rate of 60 mL h^{-1}.

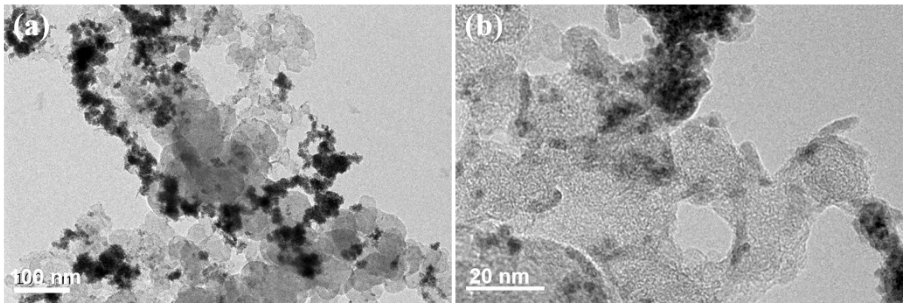

Fig. S3. Variously magnified TEM images of PtFeCu/C-EG with the pump flow rate of 60 mL h^{-1}.

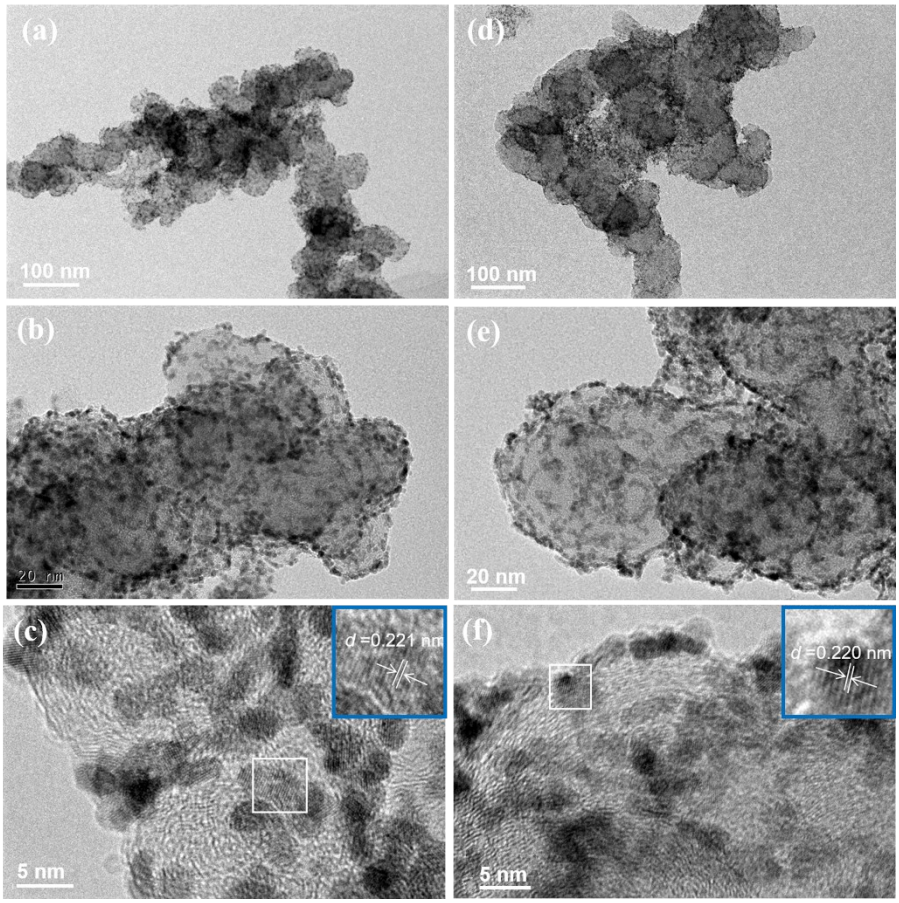

Fig. S4. Variously magnified TEM images of PtFeCu/C prepared in PEG series solvents using flow rate of 60 mL h^{-1}. (a-c) PEG400, (d-f) PEG600.

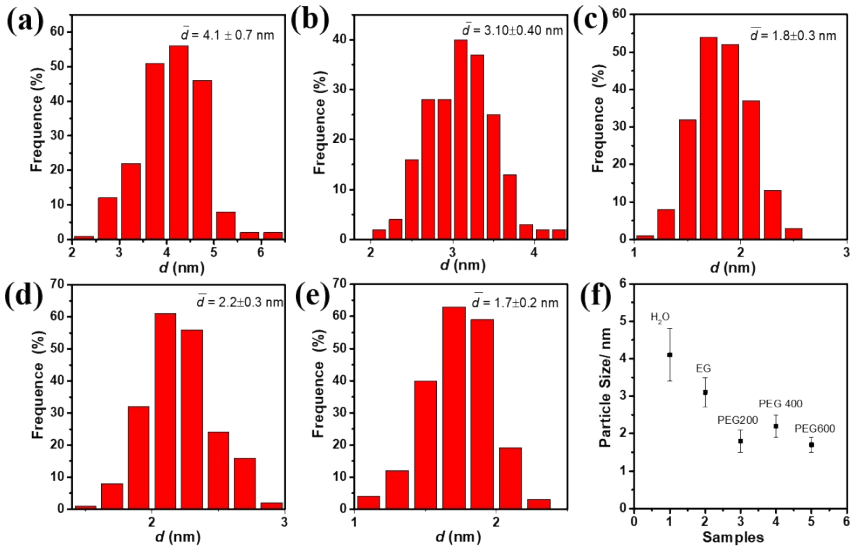

Fig. S5. Size histograms of the PtFeCu/C synthesized at a pump flow rate of 60 ml h^{-1} in different solvents respectively. (a) H_2O, (b) EG, (c) PEG200, (d) PEG400, (e) PEG600, (f) Particle size of different samples obtained in the above solvents.

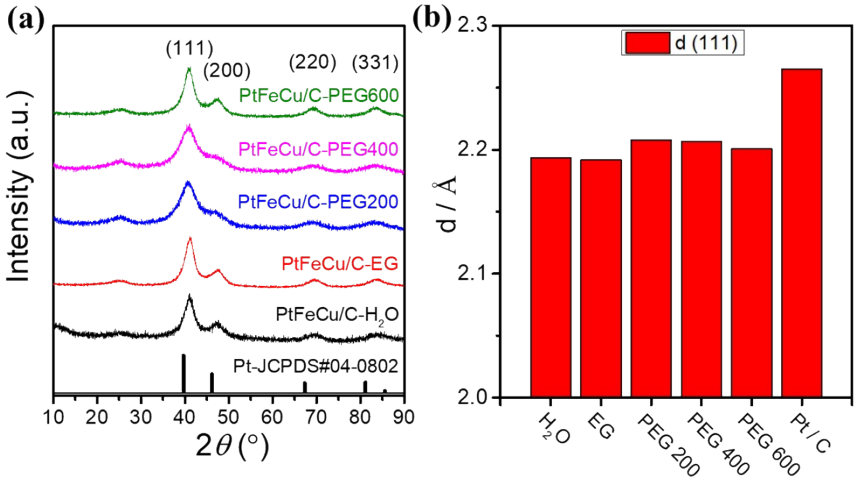

Fig. S6. (a) The XRD patterns of the PtFeCu/C synthesized in H_2O, EG, PEG200, PEG400, and PEG600. (b) The distance of (111) plane for PtFeCu/C synthesized in different solvents.

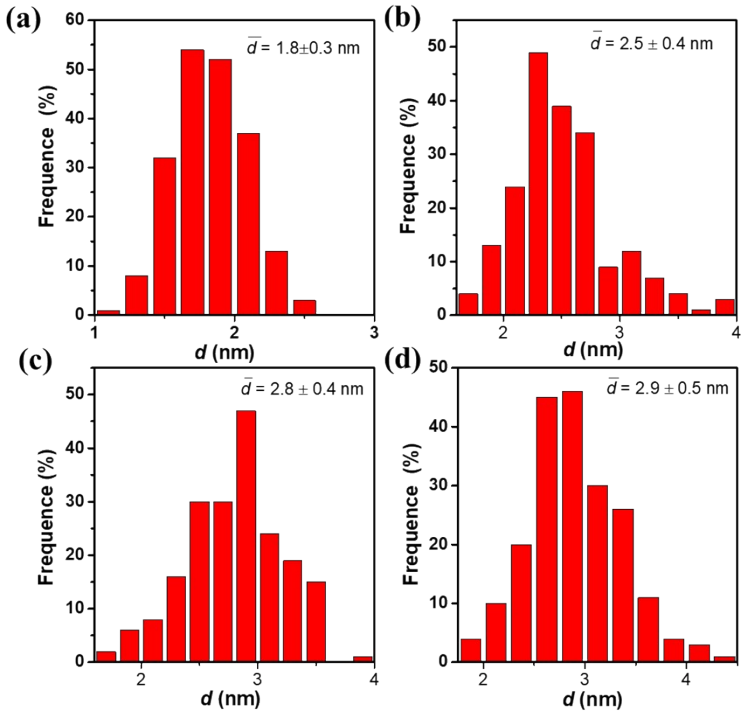

Fig. S7. Size histograms of the PtFeCu/C synthesized at varying pump flow speed. (a) 60 mL h^{-1}, (b) 300 mL h^{-1}, (c) 600 mL h^{-1}, (d) 1200 mL h^{-1}.

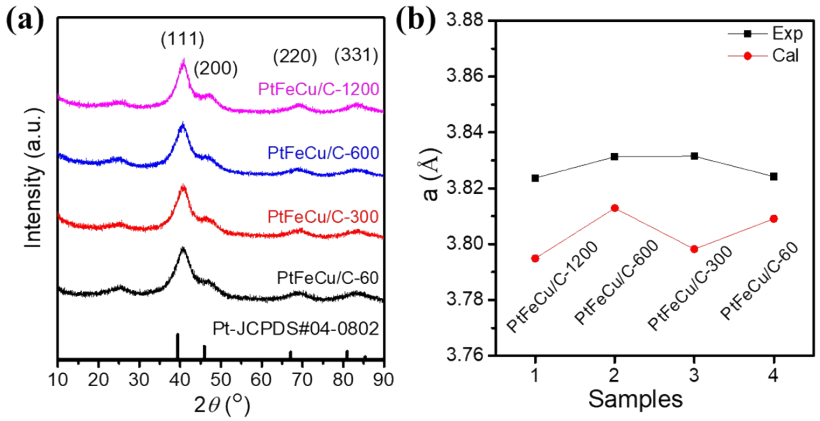

Fig. S8. (a) The XRD patterns of the PtFeCu/C synthesized in PEG200 with different pump flow speeds. (b) Calculated and experimental lattice parameters of samples obtained in varying flow rates.

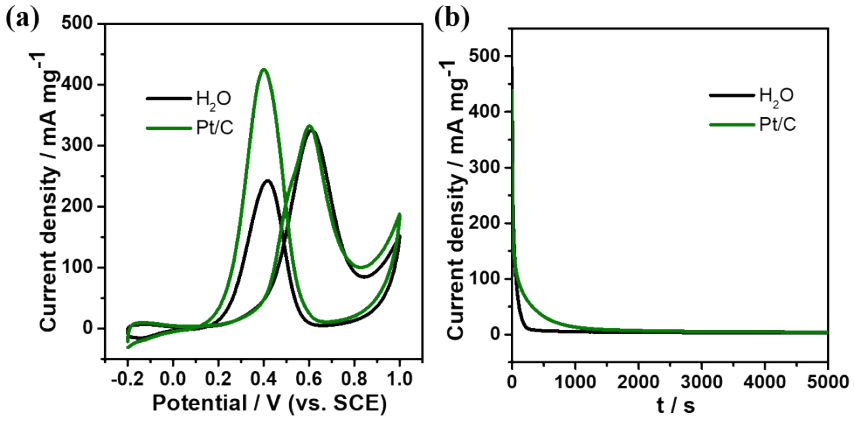

Fig. S9. Electrocatalytic properties of the PtFeCu/C synthesized in water solvent for methanol oxidation reaction (MOR). (a) Cyclic voltammetry curves of the PtFeCu/C obtained in water and commercial Pt/C in a N_2-saturated 0.5 mol/L H_2SO_4 +0.5 mol/L CH_3OH solution. Scanning rate is 50 mV/s. The currents were normalized by the mass on the GC surface. (b) Current-time curves of the catalyst and Pt/C recorded for 5000 s at 0.6V.

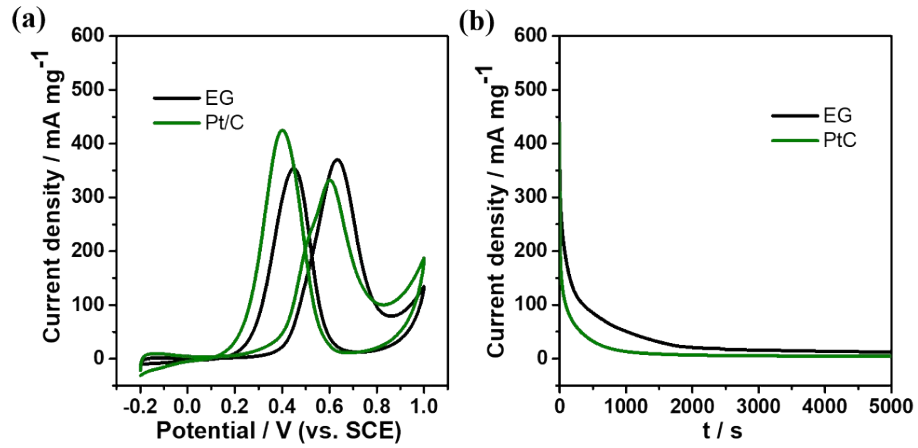

Fig. S10. Electrocatalytic properties of the PtFeCu/C synthesized in EG solvent for MOR. (a) Cyclic voltammetry curves of PtFeCu/C synthesized in EG and commercial Pt/C in a N_2-saturated 0.5 mol/L H_2SO_4 + 0.5 mol/L CH_3OH solution. Scanning rate is 50 mV/s. The currents were normalized by the mass on the GC surface. (b) Current-time curves of the catalyst and Pt/C recorded for 5000 s at 0.6 V.

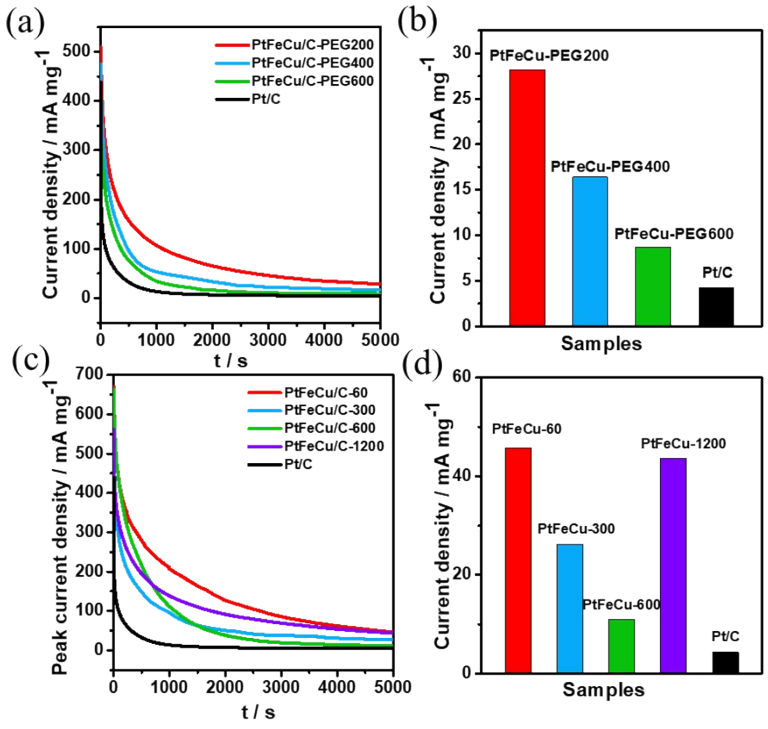

Fig. S11. (a) Chronoamperometric curves measured at 0.6 V for PtFeCu/C synthesized using PEG 200, 400 and 600, respectively, (b) Comparison of MOR current density at 5000 s in (a), (c) Chronoamperometric curves measured at 0.6 V for PtFeCu/C synthesized using PEG 200 at various flow rates, (d) Comparison of MOR current density at 5000 s in (c).

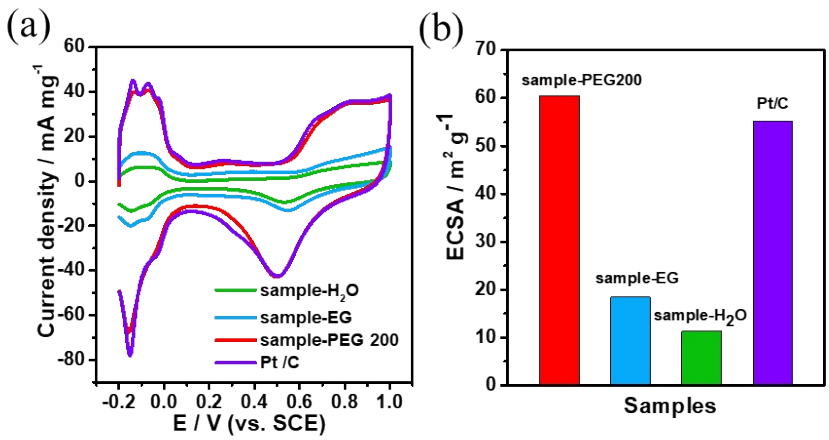

Fig. S12. Cyclic voltammetry curves and ECSA comparison of the PtFeCu/C obtained in different solvents and commercial Pt/C for MOR. (a) Cyclic voltammetry curves of the PtFeCu/C obtained in different solvents and commercial Pt/C in a N_2-saturated 0.5 mol/L H_2SO_4 solution. Scanning rate is 50 mV/s. The currents were normalized by the mass on the GC surface, (b) Comparison of ECSA of the catalysts prepared in different solvents and Pt/C.

Supplementary Table

Table S1. The distance of (111) plane, lattice constant (a), diameter and full width at half maximum (FWHM) for PtFeCu/XC-72 synthesized in H_2O, EG, PEG solvent series.

Samples	2ϑ	*d*(111)/Å	a/Å	D/nm	FWHM
PtFeCu/C-H_2O	41.113	2.1937	3.7996	2.08	0.705
PtFeCu/C-EG	41.153	2.1917	3.7961	1.55	0.947
PtFeCu/C-PEG200	40.838	2.2079	3.8242	1.47	0.998
PtFeCu/C-PEG400	40.857	2.2068	3.8223	1.48	0.991
PtFeCu/C-PEG600	40.977	2.2007	3.8117	1.62	0.902
PDF#04-0802	39.76	2.265	3.9231	-	-

Table S2. Pt loading, atomic ratio, ICP-AES composition and lattice constant calculated according to Vegard's law of PtFeCu/C in varying solvents.

Samples	Pt Loading	Atomic ratio (Pt：Cu：Fe)	ICP Composition	a/Å
PtFeCu/C-H_2O	25.76%	40.32%: 33.47%: 26.21%	$Pt_{40}Cu_{26}Fe_{34}$	3.7329
PtFeCu/C-EG	29.94%	58.01%: 25.70%: 16.29%	$Pt_{58}Cu_{26}Fe_{16}$	3.7898
PtFeCu/C-PEG 200	30.66%	57.50%: 20.80%: 21.70%	$Pt_{57}Cu_{21}Fe_{22}$	3.7869
PtFeCu/C-PEG 400	33.11%	56.82%: 22.53%: 20.65%	$Pt_{57}Cu_{23}Fe_{21}$	3.7851
PtFeCu/C-PEG 600	26.11%	54.06%: 24.39%: 21.55%	$Pt_{54}Cu_{24}Fe_{22}$	3.7764

Table S3. The bulk composition and surface composition of PtFeCu/C obtained from PEG 200, EG and H_2O.

Samples	The bulk atom percent of PtFeCu			The surface atom percent of PtFeCu		
	Pt/%	Fe/%	Cu/%	Pt/%	Fe/%	Cu/%
PtFeCu/C-PEG 200	53	18	29	53	26	21
PtFeCu/C-EG	59	11	30	51	31	18
PtFeCu/C-H_2O	40	26	34	29	56	15

Table S4. XPS analysis result of Pt 4f, Cu 2p, Fe 2p spectra in PtFeCu/C-PEG200, PtFeCu/C-EG and PtFeCu/C-H_2O.

Samples	Species	Binding energy	Assignment	Atomic ratio (%)
PtFeCu/C-PEG 200	Pt $4f_{7/2}$	71.35	Pt	41.7
		71.33	PtO	45.5
		70.25	PtO_2	12.8
	Cu $2p_{3/2}$	933.26	Cu	58.3
		933.27	CuO_x	41.7
	Fe $2p_{3/2}$	712.10	Fe	42.3
		720.06	FeO_x	57.7
PtFeCu/C-EG	Pt $4f_{7/2}$	71.33	Pt	55.2
		72.05	PtO	44.8
	Cu $2p_{3/2}$	931.29	Cu	57.5
		933.39	CuO_x	42.5
	Fe $2p_{3/2}$	711.83	Fe	56.7
		718.07	FeO_x	43.3
PtFeCu/C-H_2O	Pt $4f_{7/2}$	70.25	Pt	52.5
		72	PtO	28.5
		74.38	PtO_2	19.0
	Cu $2p_{3/2}$	932.2	Cu	55.5
		933.43	CuO_x	45.5
	Fe $2p_{3/2}$	711.82	Fe	54.5
		715.90	FeO_x	45.5

Table S5. Pt loading, atomic ratio and ICP-AES composition results for PtFeCu/C in varying pump flow speed.

Pump speed (mL h^{-1})	Pt Loading	Atomic Ratio (Pt：Cu：Fe)	ICP Composition	a (Å)
1200	35.23 %	59.72%: 22.38%: 17.90%	$Pt_{60}Cu_{22}Fe_{18}$	3.7947
600	33.87 %	65.08%: 24.10%: 10.82%	$Pt_{65}Cu_{24}Fe_{11}$	3.8129
300	33.16 %	60.77%: 22.31%: 16.92%	$Pt_{61}Cu_{22}Fe_{17}$	3.7982
60	33.20 %	64.02%: 23.06%: 12.92%	$Pt_{64}Cu_{23}Fe_{13}$	3.8091

Table S6. The distance of (111) plane, lattice constant, diameter and full width at half maximum (FWHM) for PtFeCu/C synthesized in varying pump flow rate.

Samples	2ϑ	ϑ	d(111)/Å	a	D/nm	FWHM
PtFeCu/C-1200	40.842	20.421	2.2076	3.8237	2.3559	0.621
PtFeCu/C-600	40.757	20.3785	2.2120	3.8313	1.6397	0.892
PtFeCu/C-300	40.757	20.3785	2.2121	3.8315	1.5985	0.915
PtFeCu/C-60	40.838	20.419	2.2079	3.8242	1.4660	0.998
Pt/C	39.76	19.88	2.265	3.9231	2.2685	–